## REMARKS

The Office Action of May 13, 2008 has been received and its contents carefully considered.

The present Amendment cancels claims 1-3 and 33-38. It also places claims 4-7 in independent form. In addition, the Amendment revises the claims to correct inadvertent informalities and to improve the form of the claims under US claim-drafting practice.

Since section 1 of the Office Action only "objects" to claims 5-7, which have now been placed in independent form, it is respectfully submitted that they are now in condition for immediate allowance.

Turning next to sections 3-8 of the Office Action, the present Amendment forwards a Substitute Specification to improve the idiomatic English, correct inadvertent informalities, and adopt the abstract to US practice. A marked-up copy is also attached to show the changes that have been included to the Substitute Specification (although the Substitute Specification includes improvements in formatting that cannot be shown in the marked-up copy because formatting changes cannot be identified using strike-throughs and underlining.

Pursuant to 37 CFR 1.125, the undersigned attorney states that he believes that the attached Substitute Specification contains no new matter. The Examiner is urged to review the marked-up copy to confirm for himself that new matter has not been added.

It is noted that the Substitute Specification does not augment what is said about Figures 1-8, despite the objection in section 7 of the Office Action. This objection is respectfully traversed, on the ground that Figures 1-8 are self-explanatory. Consider Figures 2-4, which show what the application calls the "first form" or layout of a constellation diagram. In Figure 2, four-bit values have been assigned to the 16 constellation points that are shown. In Figure 3, which includes the legend "First bit," half of these constellation points are enclosed in a rectangle and are marked "1." Returning to Figure 2, it will be seeing that the constellation points in question are those in which the MSB is "1." Figure 3 also shows a second diagram with the legend "Second bit," and a rectangle around half of the constellation points. Figure 2 shows that these are the constellation bits where the bit just prior to the MSB is 1. Similarly, rectangles in Figure

4 show constellation points where the third bit is 1, in constellation points where the LSB is 1.

Figures 5-7 pertain to what the application calls the "second form" of the constellation diagram. Figures 6 and 7 show rectangles to identify regions where the first, second, third, and forth bits are 1 in the second form.

In view of these considerations, it is respectfully submitted that an ordinarily skilled person who considered these figures would understand their content despite the sparsity of discussion of them in the specification. Accordingly, the objection should be withdrawn.

Section 10 of the Office Action rejects claims 33-38 for non-enablement. These claims have been canceled, so the rejection is moot.

Section 11 of the Office Action rejects claim 8 for non-enablement. In response, the present Amendment revises claim 8 to refer to a "mathematical expression "(A)" and to depend from claim 7 rather than claim 3. Since claim 7 defines mathematical expression "(A)," which was formally called "mathematical expression 24," it is respectfully submitted that the rejection has been overcome.

Section 12 of the Office Action rejects claim 21 on the ground that it does not include mathematical expressions 30 and 32. As was the case with claim 8, the present Amendment revises the claims to refer to mathematical expression by letter and to depend from earlier claims where the mathematical expressions are defined. Accordingly, it is respectfully submitted that this rejection has also been overcome.

Section 14 of the Office Action rejects various claims for indefiniteness due to the terms "first form" and "second form." The present Amendment deletes these terms from the claims, so it is respectfully submitted that the rejection has been overcome.

Section 16 of the Office Action rejects various claims for anticipation by US patent 6,507,619 to Thomson et al. This reference will hereafter be called simply "Thomson" for the sake of convenient discussion.

Claims 1-3 and 33-38 have been cancelled, so the rejection is moot with respect to those claims. Other than objected-to claims that have been placed in independent form, claim 4 is the only independent claim that stands rejected on the basis of Thomson. For the reasons discussed below, it is respectfully submitted that the invention defined by

claim 4 is not anticipated by Thomson, and is not rendered obvious by the reference, either.

Claim 4 recites that:

> … the demodulation method of the conditional probability vector corresponding to an odd-ordered bit is the same as a calculation method of the conditional probability vector corresponding to the next even-ordered bit, where the received signal value used to calculate the conditional probability vector corresponding to the odd-ordered bit uses one of the α and β according to a given combination constellation diagram and the received signal value for the even-ordered bit uses the remaining one of α and β

Section 20 of the Office Action, which addresses claim 4, relies on the passage at column 6 of Thomson, lines 9-39. It is respectfully submitted that an ordinarily skilled person who read this passage would believe that, in Thomson's technique, bits 0 and 1 are demodulated by α (the in-phase component) and bits 2 and 3 are modulated by β (the quadrature component), or the method for determining bits 0 and 1 is the same as the method for bits 2 and 3 but α is swapped with β.

In Thomson, though, the calculation method to determine the first bit (bit 0) is not the same as method used to determine the second bit (bit 1), in contrast to claim 4. Furthermore, the third and forth bits (bits 2 and 3) are determined using the same calculation method. Accordingly, it is respectfully submitted that the invention defined by claim 4 is not anticipated by Thomson. Nor would an ordinarily skilled person would have an incentive to modify what Thomson discloses so as to achieve the invention of claim 4.

The remaining claims that have been rejected depend from claim 4 and recite additional limitations to further define the invention, so they are automatically patentable along with claim 4 and need not be further discussed.

It is noted that this application has now been amended to include four independent claims. Accordingly, an additional claim fee of $105 is included in a remittance that is being submitted concurrently. Should this remittance be accidentally missing or insufficient, though, any fees that may be needed can be charged to our Deposit Account number 18-0002.

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For the foregoing reasons, it is respectfully submitted that this application is now in condition for allowance. Reconsideration of the application is therefore respectfully requested.

Respectfully submitted,

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# A DEMODULATION METHOD USING SOFT DECISION FOR QUADRATURE AMPLITUDE MODULATION AND APPARATUS THEREOF

## Technical Field

The present invention relates to a soft decision demodulation ~~of an~~ technique for a Quadrature Amplitude Modulation (hereinafter, referred to as QAM) signal, and more particularly, to a soft decision demodulation method capable of enhancing ~~a process~~ the processing speed of soft decision demodulation. ~~using predetermined function and pattern upon demodulating a received signal.~~

## Background Art

The QAM scheme is capable of ~~transmitting~~ transmissions loading two or more bits [[to]] onto a given waveform symbol, whose waveform can be mathematically expressed in two real numbers and imaginary numbers that do not interfere with each other. That is, in [[a]] the complex number imaginary number $\alpha + \beta i$, a change of the value $\alpha$ does not affect [[a]] the value $\beta$. Due to that reason, [[an]] a quadrature signal component can correspond to $\alpha$, and an in-phase signal component can correspond to $\beta$. Generally, the quadrature signal component is referred to as the Q-channel, and the in-phase component signal is referred to as the I-channel.

A constellation diagram of QAM ~~is to connect~~ plots the amplitudes of such two waves with respect to each other so as to make a number of ~~combinations,~~ combinations. The ~~position~~ positions of the combinations on a complex number plane [[to]] should have an equal conditional ~~probability,~~ probability. ~~and promise such a position.~~ Fig. 2 is a diagram showing an example of such a constellation diagram, whose size is 16 combinations. Also, each of the points shown in Fig. 2 is referred to as a constellation point. Also, ~~combinations of~~ the binary

~~numbers~~ number written under each constellation ~~diagram is symbols set to each~~ point represent the symbol assigned to that point, that is, a bundle of bits.

Generally, a QAM demodulator serves to convert signals incoming [[to]] on an I channel and an Q channel, that is, a received signal given as $\alpha + \beta i$, into the original bit bundle according to the ~~promised position~~ constellation points mentioned above, that is, the ~~combination~~ constellation diagram. ~~At this time, however,~~ However, the received signals [[are]] may not be positioned on places assigned previously, in most cases due to the effect of noise interference, and accordingly the demodulator has to restore the signals that have been converted due to [[the]] noise. ~~to the original signals.~~ ~~However, since there~~ Since it is often ~~some excessivenesses~~ desirable to guarantee [[a]] the reliability of communication in that the demodulator takes [[a]] charge of the role of noise cancellation, it is possible to embody a more effective and reliable communication system by rendering the role to the next step of a channel decoder. However, since there is an information loss in a bit quantization process performed by a binary bit detector as in a hard decision by ~~making~~ converting a demodulation signal having a continuous value to ~~correspond to~~ corresponding discrete signals of 2 levels in order to perform such a process, a similarity measure with respect to [[a]] the distance between a received signal and the ~~promised~~ constellation point is changed from a Hamming distance to [[an]] a Euclidean distance without using the binary bit detector, so that an additional gain can be obtained.

As shown in Fig. 1, in order to modulate and transmit a signal encoded by a channel encoder and demodulate the signal in a channel demodulator through a hard decision coding process, the demodulator has to have a scheme for generating the hard decision values corresponding to each of the output bits of a channel encoder from a receiving signal consisted of an in-phase signal component and a quadrature phase signal component. Such scheme generally includes two procedures, that is, a simple metric procedure proposed by Nokia company and a dual minimum metric procedure proposed by Motorola, both procedures

calculating LLR (Log Likelihood ~~Radio~~ Ratio) with respect to each of the output bits and using it as an input soft decision value of the channel demodulator.

The simple metric procedure is an event algorithm that transforms a complicated LLR calculation equation to a simple form of an approximation equation, which has a degradation of performance due to an LLR distortion caused by using the approximation equation even though it makes the LLR calculation simple. On the other hand, the dual minimum metric procedure is an event algorithm that uses the LLR calculated using a more precise approximation equation as an input of the channel demodulator, which has [[a]] the merit of considerably improving the degradation of performance caused in the case of using the simple metric procedure, but it has an expected problem that more calculations are needed compared with the simple metric procedure and an its complication is considerably increased upon embodying ~~hard-ware~~ hardware.

**Disclosure of the Invention**

Therefore, an object of the present invention is to solve the problems involved in the prior art, and to provide a soft decision scheme for demodulating a received Quadrature Amplitude Modulation (QAM) ~~receiving~~ signal ~~consisted~~ consisting of an in-phase signal component and an quadrature phase signal component, where a conditional probability vector value ~~being each of~~ (a soft decision value corresponding to a bit position of a hard decision) can be obtained using a function including a conditional determination calculation from [[an]] a quadrature phase component value and an in-phase component value of the received signal, and so it is expected that ~~process~~ processing rate can be improved and [[a]] the real manufacturing cost of ~~hard-ware~~ hardware can be reduced. In order to perform such a procedure, first, a known form of a combinational constellation diagram of QAM and its characteristic demodulation scheme will be described as follows. The combinational constellation diagram of QAM may be generally divided into 3 types or forms according to [[an]] the arrangement of

bit ~~bundle set in~~ bundles assigned to the constellation ~~point~~ points. The ~~First of it~~ first form is a form ~~constellated~~ with a constellation as shown in Figs. 2 to 4, the second is a form ~~constellated~~ with a constellation as shown in Figs. 5 to 7, and the third is a form that is not included in this application.

A characteristic of the form or case shown in Fig. 2 can be summarized as follows. In the case [[that]] where the magnitude of the QAM is $2^{2n}$, the number of bits ~~set in~~ assigned to each constellation point becomes 2n, ~~where~~ and conditional probability vector values corresponding to the first half ~~ofthe~~ of the ~~number,~~ number (that is, the first to $n^{th}$ bits) are demodulated by one of the received signals α and β and the conditional probability vector values corresponding to the second half of the ~~number,~~ number (that is, the $(n+1)^{th}$ to the $2n^{th}$ bits) are demodulated by the remaining one receiving signal. Also, an equation that is applied to both demodulations has the same procedure in the first half and second half demodulations. That is, when the value of ~~receiving~~ received signal corresponding to the second half is substituted in the first half demodulation method, the result of the second half can be obtained. (Hereinafter, such form is referred to as 'the first form').

The characteristic of the form shown in Fig. 5 can be summarized as follows. In the case [[that]] where the magnitude of the QAM is $2^{2n}$, the number of the bits ~~set in~~ assigned to each of the constellation points becomes 2n, and the demodulation method of the conditional probability vector corresponding to an odd-ordered bit is the same as the calculation method of the conditional probability vector corresponding to the next even-ordered bit. However, the ~~receiving~~ received signal value used to calculate the conditional probability vector corresponding to the odd-ordered bit uses one of α and β according to a given combination constellation diagram and the ~~receiving~~ received signal value for the even-ordered bit is used for the remaining one. In other [[word]] words, in the cases of the first and second conditional probability vector calculations, they use the same demodulation method but the values of the receiving signals are different. (Hereinafter, such form is referred to as 'the

second form').

**Brief Description of the Drawings**

The above objects, other features and advantages of the present invention will become more apparent by describing the preferred embodiment thereof with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram for explaining a general digital communication system;

Fig. 2 is a view showing a combination constellation ~~point~~ diagram for explaining a soft decision demodulation method in accordance with a first embodiment of the present invention;

Figs. 3 and 4 are views for explaining [[a]] bit ~~constellation~~ patterns in the combination constellation diagram shown in Fig. 2;

Fig. 5 is a view showing a combination constellation diagram for explaining a soft decision demodulation method in accordance with a second embodiment of the present invention;

Figs. 6 and 7 are views for explaining [[a]] bit ~~constellation~~ patterns in the combination constellation diagram shown in Fig. 5;

Fig. 8 is a view showing a conditional probability vector decision procedure in accordance with the present invention as a functional block;

Fig. 9 is an output diagram with respect to each conditional probability vector of a first form of 1024-QAM;

Fig. 10 is an output diagram with respect to each conditional probability vector of a second form of 1024-QAM;

Fig. 11 is a view showing a function applied to a first probability vector of a third embodiment of the present invention;

Fig. 12 is a view showing a function applied to a second probability vector of the third embodiment of the present invention;

Fig. 13 is a view showing a function applied to a first probability vector of the fourth embodiment of the present invention;

Fig. 14 is a view showing a function applied to a second probability vector of the fourth embodiment of the present invention; and

Fig. 15 is a view showing a ~~hard-ware~~ hardware configuration for [[a]] the soft decision of a first form of 64-QAM in accordance with the present invention.

**Best Mode for Carrying Out the Invention**

Reference will now be made in detail to [[a]] preferred ~~embodiment~~ embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

The present invention remarkably improves ~~process~~ the processing speed by applying a conditional probability vector equation instead of a log likelihood ratio method, being a soft decision demodulation method of a square constellation QAM ~~signal~~ signals that is generally used in the industry.

[[A]] The newly developed demodulation method of a square QAM signal is divided into 2 forms (see the "Disclosure of the Invention" section, above), and [[a]] first and [[a]] third embodiments are used for the first form and [[a]] second and [[a]] fourth embodiments are used for the second form. Also, an output of the final conditional probability vector value covers an area between a real number "a" and another real number "–a".

First, ~~explaining~~ several basic prerequisites will be explained before entering into the ~~description,~~ description. The [[the]] magnitude of the QAM can be characterized by the mathematical expression 1 and accordingly the number of bits ~~set in~~ assigned to each point of the constellation diagram can be characterized by the mathematical expression 2.

【mathematical expression 1】

$2^{2n}$ – QAM. n = 2, 3, 4⋯⋯

【mathematical expression 2】

the number of bits set in each point = 2n

Accordingly, the number of the conditional probability vector values, being the final output values, also becomes 2n.

Now, a first ~~one among the method~~ embodiment for demodulating [[the]] a square constellation QAM signals of the present invention will be explained.

First, a soft decision method ~~of receiving~~ for a received signal ~~of the~~ in a system using a square QAM signal constellation corresponding to the first form will be explained. In the case of the first form, although it was mentioned that one of the values of the quadrature phase component (real number part or α ) or the in-phase signal component (imaginary number part or β ) is used to calculate the conditional probability vector corresponding to the first half bit combination when explaining the characteristic of the first form were explained, the first half and the second half ~~demodulate~~ demodulation using the value β and value α respectively, for the convenience of understanding [[and]] an output area according to the demodulation is set as a value between 1 and –1 for the ~~convenience'~~ sake of convenience in the following description. Also, k is used as a parameter indicating [[an]] the order of each bit.

A method for calculating a conditional probability vector corresponding to the case [[that]] where the first [[bit,]] bit ( that is, k is 1) in the first form can be expressed as a mathematical expression 3, and Fig. 5 is a visualization of it.

【mathematical expression 3】

In the case of the first conditional probability vector (k =1), output value is determined as $\frac{1}{2^n}\beta$. However, the value of n is determined by the magnitude of QAM using the mathematical expression 1.

A method for calculating the conditional probability vector corresponding to the second bit (k = 2) in the first form can be expressed by a mathematical expression 4, and Fig. 6 is a visualization of it.

【mathematical expression 4】

In the case of the second conditional probability vector (k = 2), the output value is unconditionally determined as $c-\frac{c}{2^{n-1}}|\beta|$.

Here, n is a magnitude parameter of the QAM in the mathematical expression 1, and c is a constant.

A method for calculating a conditional probability vector corresponding to a third bit to $n^{th}$ bit (k =3, 4, ····, n-1, n) in the first form can be expressed as a mathematical expression 5. Here, as can be seen from Fig. 9, since the conditional probability vector corresponding to the third or later bit indicates a determined iteration (v shape) form, it is noted that an expression be repeatedly used using such property.

【mathematical expression 5】

First, dividing the output diagram with a basic v-shaped form, the conditional probability vector corresponding to each bit is divided into $(2^{k-3} + 1)$ areas.

② A basic expression according to the basic form is determined as $\frac{d}{2^{n-k+1}}|\beta|-d$.

③ If finding a belonging area as the given β and substituting a value of $|\beta|$-m that is subtracted a middle value m of each area (for example, since the repeated area is one when k = 4, the area becomes $2^{n-2} \leq |\beta| < 3\cdot 2^{n-2}$ and the middle value becomes $m = 2^{n-1}$) into the basic expression as a new β, the output value can be determined.

④ Finally, in the left and right outer areas among the divided areas, that is, $(2^{k-2}-1)2^{n-k+2} < |\beta|$, the output value can be determined by substituting the middle value of $m = 2^n$ and $(|\beta| - m)$ value of a new β into the basic expression.

Here, d is a constant that is changed according to a value of k.

A method for calculating the conditional probability vector corresponding to the second half bits of the first form, that is, bit number n+1 to 2n can be obtained by substituting the

β into α in the method for obtaining the conditional probability vector of the first half according to the characteristic of the first form. In other word, the condition that all of β in the mathematical expression 3 are substituted with α becomes a calculation expression of the first conditional probability vector of the second half, that is, a conditional probability vector corresponding to $(n+1)^{th}$ bit. The conditional probability vector corresponding to the $(n + 2)^{th}$ bit of the second conditional probability vector of the second half can be determined by substituting β with α in the mathematical expression (4 that is, the condition to calculate the second conditional probability vector of the first half), and the conditional probability vector corresponding to the bit number n+3 to 2n being the next case can be determined by transforming the mathematical expression to the above description.

Next, a method for performing [[a]] soft ~~decision~~ decisions of the ~~receiving~~ received signal [[of a]] in a system using a square QAM constellation corresponding to the second form will be explained. For convenience of understanding, demodulation is performed to determine the conditional probability vector corresponding to odd-ordered bits using the value of α and to determine the conditional probability vector corresponding to even-ordered bits using the value of β, and accordingly the output scope is determined between 1 and –1 as is in the first form for convenience' sake.

In the second form, a method for calculating the conditional probability vector corresponding to the first bit (k=1) can be expressed as a mathematical expression 6 and Fig. 6 is a visualization of it.

【mathematical expression 6】

ⓐ In the case of the first bit (k=1), the output value is determined as $-\frac{1}{2^2}\alpha$.

However, the value of n is determined by the mathematical expression 1 according to the magnitude of the QAM.

In the second form, the conditional probability vector corresponding to the second bit

(k=2) can be obtained by substituting the $\alpha$ with $\beta$ in the mathematical expression 6 for calculating the first conditional probability vector according to the characteristic of the second form.

In the second form, a method for calculating the conditional probability vector corresponding to the third bit (k=3) can be expressed as a mathematical expression 7.

【mathematical expression 7】

If $\alpha \cdot \beta \geq 0$,

ⓐ In the case of the third bit (k=3), the output value is determined as $\frac{c}{2^{n-1}}|\alpha|-c$ .

If $\alpha \cdot \beta < 0$, the calculation expression is determined as an expression in which all of $\alpha$ are substituted with $\beta$ in the calculation expression in the case of $\alpha \cdot \beta \geq 0$.

Here, n is a magnitude parameter of the QAM in the mathematical expression 1 and c is a constant.

As such, it can be another characteristic of the second form QAM that the conditional probability vector is obtained in the cases of $\alpha \cdot \beta \geq 0$ and $\alpha \cdot \beta < 0$ separately. Such characteristic is applied when the conditional probability vector corresponding to the third or later bit of the second form and includes a reciprocal substitution characteristic like substituting $\beta$ with $\alpha$ .

An expression to obtain the conditional probability vector corresponding to the fourth bit (k=4) of the second form can be obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the mathematical expression 7 used to obtain the third conditional probability vector according to the second form.

The expression used to obtain the conditional probability vector corresponding to the fifth bit (k=5) of the second form can be obtained by applying the mathematical expression 8. Here, as can be seen from Fig. 10, since the conditional probability vector corresponding to the fifth or later bit indicates a ~~determined an iteration (v shape)~~ v shape form, it is noted that an

expression be repeatedly used using such property. However, when the conditional probability vector corresponding to the fifth or later bit is calculated, the even-ordered determination value uses the expression that was used to calculate just before odd-ordered determination value according to the property of the second form, which is applied when the magnitude of the QAM is less than 64 only. And, when the magnitude is over 256, the remaining part can be divided into two parts and the calculation can be performed in the first half part and then in the second half part as is in the first form.

【mathematical expression 8】

If $\alpha \cdot \beta \geq 0$,

ⓐ First, on dividing the output diagram into a basic V-shaped form, the conditional probability vector corresponding to each bit can be divided into $(2^{k-5} + 1)$ areas.

ⓑ A basic expression according to a basic form is determined as $\frac{d}{2^{n-k+3}}|\alpha|-d$.

ⓒ If finding a belonging area as the given $\alpha$ and substituting a value of $|\alpha|-m$ that is subtracted a middle value m of each area (for example, since the repeated area is one when $k = 6$, the area becomes $2^{n-2} \leq |\alpha| < 3 \cdot 2^{n-2}$ and the middle value becomes $m = 2^{n-1}$) into the basic expression as a new $\alpha$, the output value can be determined.

ⓓ Finally, in the left and right outer areas among the divided areas, that is, $(2^{k-2}-1)2^{n-k+2} < |\alpha|$, the output value can be determined by substituting the middle value of $m = 2^n$ and $(|\alpha| - m)$ value of a new $\beta$ into the basic expression.

In the case of $\alpha \cdot \beta < 0$, the output value can be obtained by substituting $\alpha$ with $\beta$ in the expressions (a), (b), (c) and (d).

The calculation of the conditional probability vector corresponding to the sixth bit of the second form can be obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the mathematical expression 8 used to obtain the fifth conditional probability vector by the property of the second form in the case that the magnitude of the QAM is 64-QAM. However, in the case

that the magnitude of the QAM is more than 256-QAM, the first half is obtained by dividing total remaining vectors into 2 and the second half is obtained by substituting the received value ~~(α or β ))~~ (α or β ) into the expression of first half. At this time, changed value in the expression of first half is the received value only, and the bit number value (k) is not changed but substituted with that of first half.

Consequently, in the case that the magnitude of the QAM is more than 256, the calculation of the conditional probability vector corresponding to the fifth to $(n+2)^{th}$ bit of the second half is determined by the mathematical expression 8.

The calculation of the conditional probability vector corresponding to the (n+3)th to the last, 2nth bit of the second form is determined by substituting the parameter α with β in the mathematical expression as mentioned above.

The soft decision demodulation of the square QAM can be performed using the received signal, that is, α + β i through the procedure described above. However, it is noted that although the method described above arbitrarily determined an order in selecting the received signal and substituting it into a determination expression for convenience of understanding, the method is applied [[in]] more ~~general~~ generally in real ~~application~~ applications so that the character α or β expressed in the mathematical expressions can be freely exchanged each other according to the combination constellation form of the QAM, and the scope of the output values may be nonsymmetrical such as values between a and b, as well as values between a and –a. ~~It can be said that such~~ This fact enlarges the generality of the present invention, so that it increases its significance. Also, although the mathematical expressions described above seems to be very complicated, they are generalized for general applications so that it is realized that they are very simple viewing them through ~~really~~ applied embodiments.

**First Embodiment**

The first embodiment of the present invention is a case corresponding to the first form. ~~and is applied the property of the first form.~~ The first embodiment includes an example of 1024-QAM where the magnitude of QAM is 1024. The order selection of the received signal is intended to apply α in the first half and β in the second half.

Basically, QAM in two embodiments of the present invention can be determined as in the following expression. A mathematical expression 1 determines the magnitude of QAM and a mathematical expression 2 shows the number of bits set in each point of a combination constellation diagram according to the magnitude of QAM.

【mathematical expression 1】

$2^{2n}$ – QAM, n = 2, 3, 4 ····

【mathematical expression 2】

the number of bits set in each point = 2n

Basically, the magnitude of QAM in the first embodiment of the present invention is determined as the following expression, and accordingly the conditional probability vector value of the final output value becomes 2n.

A case where $2^{2*5}$ – QAM equals to 1024 – QAM according to the mathematical expression 1 and the number of bits set in each constellation point equals to 2 x 5 = 10 bits according to the mathematical expression 2 will be explained using such mathematical expressions 1 and 2. First, prior to entering into calculation expression applications, it is noted that if a calculation expression for 5 bits of the first half among 10 bits are known by the property of the first form, a calculation expression for remaining 5 bits of the second half is also known directly.

First, the first conditional probability vector expression is a case of k=1, and has its output value determined as $\frac{1}{2^5}\beta$ unconditionally.

Next, the second (that is, k=2) conditional probability vector has its output value of

$c-\frac{c}{2^4}|\beta|$ . Here, c is a constant.

Next, the third (k=3) conditional probability vector calculation expression is given as follows, where the basic expression according to the basic form is determined as $\frac{d}{2^3}|\beta|-d$ .

At this time, the calculation is divided into 2 areas, and the output value is determined as $\frac{d}{2^3}|\beta|-d$ if $|\beta|<2^4$, and the output value is determined as $\frac{d}{2^3}||\beta|-32|-d$ for the other cases.

Next, the fourth (k=4) conditional probability vector calculation expression is given as follows, where the basic expression according to the basic form is determined as $\frac{d}{2^2}|\beta|-d$ and divided into 3 areas.

Here, the output value is determined as $\frac{d}{2^2}|\beta|-d$ if $|\beta|<2^3$, the output value is determined as $\frac{d}{2^2}||\beta|-16|-d$ if $2^3\leq|\beta|<3\cdot2^3$, and the output value is determined as $\frac{d}{2^2}||\beta|-32|-d$ for the other case.

Next, the calculation expression of the fifth (k=5) conditional probability vector is given as follows, where a basic expression according to the basic expression is determined as $\frac{d}{2}|\beta|-d$ and is divided into 5 areas. Here, the output value is determined as $\frac{d}{2}|\beta|-d$ if $|\beta|<2^2$.

And the output value is determined as $\frac{d}{2}||\beta|-8|-d$ if $2^2\leq|\beta|<3\cdot2^2$, the output is determined as $\frac{d}{2}||\beta|-16|-d$ if $3\cdot2^2\leq|\beta|<5\cdot2^2$, the output value is determined as $\frac{d}{2}||\beta|-24|-d$

if $5\cdot 2^2 \le |\beta| < 7\cdot 2^2$, and the output value is determined as $\frac{d}{2}||\beta|-32|-d$ for the other cases.

Next, the calculation expression of $6^{th}$ to $10^{th}$ conditional probability vector is implemented by substituting $\alpha + \beta$ with $\alpha + \beta$ in the first to fifth conditional probability vectors according to the property of the first form.

**Second Embodiment**

The second embodiment of the present invention is a case corresponding to the second form. ~~and is applied the property of the second form.~~ The second embodiment includes an example of 1024-QAM where the magnitude of QAM is 1024. The order selection of the received signal is intended to apply $\alpha$ first.

As [[is]] in the first embodiment, the mathematical expression 1 determines the magnitude of the QAM, and the mathematical expression 2 indicates the number of bits set in each point of the combination constellation diagram according to the magnitude of the QAM.

【mathematical expression 1】

$2^{2n}$ – QAM, n = 2, 3, 4 ····

【mathematical expression 2】

the number of bits set in each point = 2n

Basically, the magnitude of QAM in the second embodiment of the present invention is determined as the above expression, and accordingly the conditional probability vector value of the final output value becomes 2n.

A case where n equals to 5, that is, $2^{2*5}$ – QAM equals to 1024 – QAM according to the mathematical expression 1 and the number of bits set in each constellation point equals to 2 x 5 = 10 bits according to the mathematical expression 2 will be explained when n is 5 using such mathematical expressions 1 and 2.

First, the first conditional probability vector calculation is a case of k=1, where the

output value is determined as $\frac{1}{2^5}a$ unconditionally.

Next, the second (k=2) conditional probability vector calculation expression is a case where the first calculation expression is substituted, where the output value is determined as $\frac{1}{2^5}\beta$.

Next, for the third (k=3) conditional probability vector calculation expression, when α β ≥ 0, the following will be given, where the output value is determined as $c-\frac{c}{2^4}|a|$ unconditionally.

However, c is a constant.

When α β <0, this calculation expression is obtained by substituting α with β in the expression used for the method for determining the output of the third conditional probability vector explained just above (α β ≥ 0).

Next, for the fourth (k=4) conditional probability vector calculation,

(1) when α β ≥ 0, the following will be given, where the output value is determined as $c-\frac{c}{2^4}|\beta|$ unconditionally.

(2) When α β <0, this calculation expression is obtained by substituting α with β in the expression used for the method for determining the output of the fourth conditional probability vector explained just above (α β ≥ 0).

Next, for the fifth (that is, k=5) conditional probability vector calculation expression, when α β ≥ 0, the following will be given, where a basic expression according to the basic form is determined as $\frac{d}{2^3}|a|-d$.

Here, the expression is divided into 2 areas, where if |α |<$2^4$, the output value is

determined as $\frac{d}{2^3}|a|-d$, and the output value is determined as $\frac{d}{2^3}||\alpha|-32|-d$ for other cases.

(2) When α β <0, this calculation expression is obtained by substituting α with β in the expression used for the method for determining the output of the fifth conditional probability vector explained just above (α β ≥ 0).

Next, for the sixth conditional probability vector (that is, k=6), when α β ≥ 0, a basic expression according to the basic form is determined as $\frac{d}{2^2}|a|-d$, and here, the expression is divided into 3 areas, where if |α |<$2^3$, the output value is determined as $\frac{d}{2^2}|a|-d$, the output value is determined as $\frac{d}{2^2}||a|-16|-d$, and the output value is determined as $\frac{d}{2^2}||\alpha|-32|-d$ for other cases.

When α β <0, this calculation expression is obtained by substituting α with β in the expression used for the method for determining the output of the sixth conditional probability vector explained just above (α β ≥ 0).

Next, for the calculation expression of the seventh (k=7) conditional probability vector, when α β ≥ 0, a basic expression according to the basic form is determined as $\frac{d}{2}|a|-d$, and here, the expression is divided into 5 areas,

where if |α |<$2^2$, the output value is determined as $\frac{d}{2}|a|-d$,

if $2^2$<|α |<$3\cdot2^2$, the output value is determined as $\frac{d}{2}||a|-8|-d$,

if $3\cdot2^2$<|α |<$5\cdot2^2$, the output value is determined as $\frac{d}{2}||a|-16|-d$ ,

if $5\cdot 2^2 < |\alpha| < 7\cdot 2^2$, the output value is determined as $\frac{d}{2}||\alpha|-24|-d$, and

the output value is determined as $\frac{d}{2}||\alpha|-32|-d$ for the other cases.

When $\alpha\beta < 0$, this calculation expression is obtained by substituting $\alpha$ with $\beta$ in the expression used for the method for determining the output of the seventh conditional probability vector explained just above ($\alpha\beta \geq 0$).

A method for obtaining the eighth to tenth conditional probability vectors is obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the expression to obtain the fifth to seventh conditional probability vectors.

Next, the second one of the method for demodulating square QAM signal will be explained.

First, a soft decision method of the square QAM corresponding to the first form will be explained. In the case of the first form, while anyone of the real number part and the imaginary number part among the received signal is used in order to calculate the conditional probability vector corresponding to the first half bit combination, the first half is demodulated using a value $\beta$ and the second half is demodulated using a value of $\alpha$ and it output scope is determined between 1 and –1 for convenience's sake in the following description.

The method for calculating the conditional probability vector corresponding to the first bit in the first form can be expressed as the mathematical expression 13 and Figs. 3 and 11 are the visualization of it.

【mathematical expression 13】

If $|\beta| \geq 2^n - 1$, the output is determined as sign($\beta$).

Also, ② if $|\beta| \leq 1$, the output is determined as 0.9375* sign($\beta$).

Also, ③ if $1 < |\beta| \leq 2^n - 1$, the output is determined as

$$sign(\beta)\frac{0.0625}{2^n-2}(|\beta|-1)+0.9375*sign(\beta)$$

However, the sign(β ) means a sign of the value sign β .

In the first form, a method for calculating the conditional probability vector corresponding to the second bit can be expressed as the mathematical 14 and Figs. 4 and 12 are a visualization of it.

【mathematical expression 14】

① If $2^n-2^{n(2-m)} \leq |\beta| \leq 2^n-2^{n(2-m)}+1$, the output is determined as $(-1)^{m+1}$.

Also, ② if $2^{n-1}-1 \leq |\beta| \leq 2^{n-1}+1$, the output is determined as $0.9375(2^{n-1}-|\beta|)$.

Also, ③ if $2^{n-1}-2^{(n-1)(2-m)}+m \leq |\beta| \leq 2^n-2^{(n-1)(2-m)}+m-2$, the output is determined as

$$-\frac{0.0625}{2^n-2}(|\beta|-2m+1)+0.0375(-1)^{m+1}+0.0625$$

Here, m=1 or m=2.

In the first form, a method for calculating the conditional probability vector corresponding to the third to $(n-1)^{th}$ bits can be expressed as the mathematical expression 15.

【mathematical expression 15】

① if $m*2^{n-k+2}-1 \leq |\beta| \leq m*2^{n-k+2}+1$, the output is determined as $(-1)^{m+1}$.

Also, ② if $(2\ell-1)*2^{n-k+1}-1<|\beta| \leq (2\ell-1)*2^{n-k+1}+1$, the output is determined as $(-1)^{\ell+1}0.9375\{|\beta|-(2\ell-1)*2^{n-k+1}\}$.

Also, ③ if $(P-1)*2^{n-k+1}+1<|\beta| \leq P*2^{n-k+1}-1$, the output depends on the value P, where if the P is odd number, the output is determined as

$$\frac{0.0625}{2^{n-K+1}-2}[(-1)^{((p+1)/2)+1}*|\beta|+(-1)^{(p+1)/2}[(P-1)*2^{n-k+1}+1]+(-1)^{(p+1)/2}]$$

However, if the value P is even number, the output is determined as

$$\frac{0.0625}{2^{n-K+1}-2}[(-1)^{p/2+1}*|\beta|+(-1)^{p/2}(P*2^{n-k+1}-1)]+(-1)^{p/2+1}$$

Here, m=0, 1…$2^{k-2}$, and $\ell$ =1, 2, … $2^{k-2}$, also, P=1, 2, …$2^{k-1}$.

Here, k is bit number, which is an integer more than 3.

In the first form, a method for calculating the conditional probability vector corresponding to the nth bit of the last bit in the first half can be expressed as the mathematical expression 16. That is a specific case of the mathematical expression 16, wherein k=n and the only condition expressions of ① and ② are applied.

【mathematical expression 16】

① If $m*2^2-1 \leq |\beta| \leq m*2^2+1$, the output is determined as $(-1)^{m+1}$.

Also, ② if $(2\ell-1)*2^1-1 < |\beta| < (2\ell-1)*2^1+1$, the output is determined as $0.9375\{|\beta| - (2\ell-1)*2^1\}$.

Here, m=0, 1, …$2^{n-2}$, and $\ell$ = 1, 2 …$2^{n-2}$.

A method for calculating the conditional probability vector corresponding to the second half bits of the first form, that is, bit number n+1 to 2n can be performed by substituting β with α in the method for obtaining the conditional probability vector of the first half according to the property of the first form. That is, the condition where all of β in the mathematical expression 13 is substituted with α becomes the first conditional probability vector of the second half, that is, the conditional probability vector calculation expression corresponding to the $(n+1)^{th}$ bit. Also, the conditional probability vector corresponding to the $(n+2)^{th}$ bit, that is, the second conditional probability vector of the second half can be determined by substituting β with α in the mathematical expression 14 that is the condition where the second conditional probability vector of the first half is calculated, and the conditional probability vector corresponding to the bit number n+3 to 2n, that is, the following cases, can be determined by transforming the mathematical expressions 15 and 16 as described above.

Next, a soft decision method of the received signal of a square QAM corresponding to the second form will be explained. Also, for convenience of understanding, the value α is used to determine the conditional probability vector corresponding to the odd-ordered bit and

the value β is used to determine the even-ordered bit.

In the second form, the method for calculating the conditional probability vector corresponding the first bit can be expressed as the mathematical expression 17 and Fig. 13is a visualization of it.

【mathematical expression 17】

ⓐ if $|\alpha| \geq 2^n - 1$, the output is determined as $-\mathrm{sign}(\alpha)$.

Also, ⓑ if $|\alpha| \leq 1$, the output is determined as $0.9375 * \mathrm{sign}(\alpha)$.

Also, ⓒ if $1 < |\alpha| \leq 2^n - 1$, the output is determined as $-sign(\alpha)\frac{0.0625}{2^n-2}(|\alpha|-1)+0.9375$.

However, sign(α) means the sign of the value α.

In the second form, a method for calculating the conditional probability vector corresponding to the second bit can be obtained by substituting all of α with β in the mathematical expression 17 used to calculate the first conditional probability vector according to the property of the second form.

In the second form, the method for calculating the conditional probability vector corresponding to the third bit can be expressed as the mathematical expression 18.

【mathematical expression 18】

When $\alpha \times \beta \geq 0$,

ⓐ if $2^n - 2^{n(2-m)} \leq |\alpha| \leq 2^n - 2^{n(2-m)} + 1$, the output is determined as $(-1)^m$.

Also, ⓑ if $2^{n-1} - 1 \leq |\alpha| \leq 2^{n-1} + 1$, the output is determined as $0.9375(|\beta| - 2^{n-1})$.

Also, ⓒ if $2^{n-1} - 2^{(n-1)(2-m)} + m \leq |\alpha| \leq 2^n - 2^{(n-1)(2-m)} + m - 2$, the output is determined as

$\frac{0.0625}{2^n-2}(|\alpha|-2m+1)+0.9735(-1)^m-0.0625.$

If $\alpha \times \beta < 0$, the calculation expression is determined as an expression where all of α are substituted with β in the calculation expression of the case of $\alpha \times \beta \geq 0$.

As such, the method for obtaining the conditional probability vector in each cases of

$\alpha \times \beta \geq 0$ and $\alpha \times \beta < 0$ can be said to be another property. Such property is always applied when obtaining the conditional probability vector corresponding to the third or later bit of the second form, and the mutual substitution property such as substituting $\beta$ with $\alpha$ is also included in this property.

The expression for obtaining the conditional probability vector corresponding to the fourth bit of the second form is obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the mathematical expression 18 used to obtain the third conditional probability vector by the property of the second form in the case that the magnitude of the QAM is less than 64-QAM. However, the case where the magnitude of QAM is more than 256-QAM is expressed as the mathematical expression 19.

【mathematical expression 19】

ⓐ if $m*2^{n-k+3}-1 \leq |\alpha| \leq m*2^{n-k+3}+1$, the output is determined as $(-1)^{m+1}$.

Also, ⓑ if $(2\ell-1)*2^{n-k+2}-1 < |\alpha| < (2\ell-1)*2^{n-k+2}+1$, the output is determined as $(-1)^{\ell+1}\{0.9375|\alpha|-0.9375(2\ell-1)*2^{n-k+2}\}$.

Also, ⓒ if $(P-1)*2^{n-k+2}+1 < |\alpha| \leq P*2^{n-k+2}-1$, the output is determined according to the value P, where if P is an odd number, the output is determined as

$$\frac{0.0625}{2^{n-K+2}-2}[(-1)^{(p+1)/2+1}*|\alpha|+(-1)^{(p+1)/2}[(P-1)*2^{n-k+2}+1]]+(-1)^{(p+1)/2},$$

if P is an even number, the output is determined as

$$\frac{0.0625}{2^{n-K+2}-2}[(-1)^{p/2+1}*|\alpha|+(-1)^{p/2}(P*2^{n-k+2}-1)]+(-1)^{p/2+1}]$$

Here, k is a bit number, and $m=0, 1, \ldots 2^{k-3}$, $\ell=1, 2, \ldots, 2^{k-3}$, $p=1, 2, \ldots 2^{k-2}$.

An expression for obtaining the conditional probability vector corresponding to the fifth bit of the second form can be expressed as the mathematical expression 20 in the case that the magnitude of QAM is 64-QAM and can be applied the mathematical expression 19 in the case that the magnitude of QAM is more than 256-QAM.

【mathematical expression 20】

When $\alpha \times \beta \geq 0$,

ⓐ if $m*2^2 -1<|\beta| \leq m*2^2 +1$, the output is determined as $(-1)^{m+1}$.

ⓑ If $(2\ell -1)*2^2 -1 <|\beta| \leq (2\ell -1)*2^2+1$, the output is determined as $0.9375(-1)^{\ell+1}\{|\beta|-(2\ell -1)*2^2\}$.

Here, m=0, 1, 2 and $\ell$ =1, 2.

If $\alpha \times \beta <0$, the output is obtained by substituting $\beta$ with $\alpha$ in the expressions ⓐ and ⓑ according to the property of the second form.

The calculation of the conditional probability vector corresponding to the sixth bit of the second form is obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the mathematical expression 20 that is an expression used to obtain the fifth conditional probability vector according to the property of the second form in the case that the magnitude of QAM is 64-QAM. However, a case where the magnitude of QAM is more than 256-QAM is expressed as the mathematical expression 19.

A calculation of the conditional probability vector corresponding to the seventh to $n^{th}$ bit of the second form is determined as the mathematical expression 19.

A calculation of the conditional probability vector corresponding to the (n+1)th bit of the second form is expressed as the mathematical expression 21 and this is a specific case of the mathematical expression 19.

【mathematical expression 21】

ⓐ if $m*2^2 -1\leq |\alpha| \leq m*2^2 +1$, the output is determined as $(-1)^{m+1}$.

Also, ⓑ If $(2\ell -1)*2^1 -1 <|\alpha| \leq (2\ell -1)*2^1+1$, the output is determined as $(-1)^{\ell+1}\{0.9375|\alpha|-0.9375(2\ell -1)*2^1\}$.

Here, m=0, 1,... $2^{n-2}$ and $\ell$ =1, 2...$2^{n-2}$.

A calculation of the conditional probability vector corresponding to the $(n+2)^{th}$ bit of the second form is obtained by substituting $\alpha$ with $\beta$ and $\beta$ with $\alpha$ in the mathematical

expression 18.

A calculation of the conditional probability vector corresponding to the $(n+3)^{th}$ to $(2n-1)^{th}$ bit of the second form is obtained by substituting $\alpha$ with $\beta$ in the mathematical expression 19. However, the bit number of the value k that is used at this time is 4 to n, which is sequentially substituted instead of n+3 to 2n-1.

A soft decision demodulation of the square QAM can be implemented using the received signal, that is, the value of $\alpha + \beta i$ through such process. However, although the method described above arbitrarily decided the order in selecting the received signal and substituting that into the determination expression for the convenience of understanding, it is noted that it is applied in more general in its real application so that the character $\alpha$ or $\beta$ expressed in the expression can be freely exchanged according to the combination constellation form of the QAM and the scope of the output value can be asymmetrical such as a value between "a" and "b" as well as a value of "a" or "–a". That enlarges the generality of the present invention and increases its significance. Also, although the mathematical expressions described above seems to be very complicated, they are generalized for general applications so that it is realized that they are very simple viewing them through really applied embodiments.

**Third Embodiment**

The third embodiment of the present invention is a case corresponding to the first form and is applied the property of the first form. The third embodiment includes an example of 1024-QAM where the magnitude of QAM is 1024. The order selection of the received signal is intended to apply $\alpha$ in the first half and $\beta$ in the second half. (referring to Figs. 11 and 12).

Basically, QAM in two embodiments of the present invention can be determined as following expression. A mathematical expression 1 determines the magnitude of QAM and a mathematical expression 2 shows the number of bits set in each point of a combination

constellation diagram according to the magnitude of QAM.

【mathematical expression 1】

$2^{2n}$ – QAM, n = 2, 3, 4 ····

【mathematical expression 2】

the number of bits set in each point = 2n

Basically, the magnitude of QAM in the third embodiment of the present invention is determined as the following expression, and accordingly the number of the conditional probability vector value of the final output value becomes 2n.

A case where $2^{2*5}$ – QAM equals to 1024 – QAM according to the mathematical expression 1 and the number of bits set in each constellation point equals to 2 x 5 = 10 bits according to the mathematical expression 2 will be explained when n is 5 using such mathematical expressions 1 and 2. First, prior to entering into calculation expression applications, it is noted that if a calculation expression for 5 bits of the first half among 10 bits are known by the property of the first form, a calculation expression for remaining 5 bits of the second half is also known directly.

First, for the first conditional probability vector calculation expression, if $|\beta| > 2^5-1$, the output is determined as sign(β ).

However, ② if $|\beta| \leq 1$, the output is determined as 0.9375*sign(β ).

Also, ③ if $1 < |\beta| \leq 2^5-1$, the output is determined as $sign(\beta)\left[\frac{0.0625}{2^5-2}(|\beta|-1)+0.9375\right]$.

Next, for the second (that is, k=2, m=1, 2) conditional probability vector, if $0 \leq |\beta| \leq 1$, the output is determined as 1.

Also, if $2^5-1 \leq |\beta| \leq 2^5$, the output is determined as –1.

Also, if $2^4-1 \leq |\beta| \leq 2^4+1$, the output is determined as $0.9375(2^4-|\beta|)$.

Also, if $1 \leq |\beta| \leq 2^4-1$, the output is determined as $-\frac{0.0625}{2^4-2}(|\beta|-1)+1$, and if

$2^4+1 \leq |\beta| \leq 2^5-1$, the output is determined as $-\frac{0.0625}{2^4-2}(|\beta|-3)-0.825$.

Next, for the third (that is, k=3, m=0, 1, 2, $\ell$ =1, 2, p=1, 2, 3, 4) conditional probability vector calculation expression,

① If $m*2^4-1 \leq |\beta| \leq m*2^4+1$, the output is determined as $(-1)^{m+1}$.

At this time, when substituting m=0, 1, 2, if $-1 < |\beta| \leq 1$, the output is determined as 1.

Also, if $2^4-1 < |\beta| \leq 2^4+1$, the output is determined as 1.

Also, if $2^5-1 < |\beta| \leq 2^5+1$, the output is determined as –1.

Also, ② if $(2\ell-1)*2^3-1 < |\beta| \leq (2\ell-1)*2^3+1$, the output is determined by substituting $\ell$ =1,2 into $(-1)^{\ell+1}0.9375\{|\beta|-(2\ell-1)*2^3\}$. Here, if $2^3-1 < |\beta| \leq 2^3+1$, the output is determined as $0.9375(|\beta|-2^3)$, and if $3*2^3-1 < |\beta| \leq 3*2^3+1$, the output is determined as $-0.9375(|\beta|-3*2^3)$.

Also, ③ when $(P-1)*2^3+1 < |\beta| \leq P*2^3-1$ and substituting P=1, 2, 3 and 4 according to whether P is odd number or even number, if $1 < |\beta| \leq 2^3-1$, the output is determined as

$\frac{0.0625}{2^3-2}(|\beta|-1)-1$,

also, if $2^3+1 < |\beta| \leq 2^4-1$, the output is determined as $\frac{0.0625}{2^3-2}(|\beta|-2^4+1)+1$,

also, if $2^4+1 < |\beta| \leq 3*2^3-1$, the output is determined as $\frac{0.0625}{2^3-2}(2^4+1-|\beta|)+1$,

also, $3*2^3+1 < |\beta| \leq 2^5-1$, the output is determined as $\frac{0.0625}{2^3-2}(2^5+1-|\beta|)-1$.

Next, for the fourth (that is, k=4, m=0, 1, 2, 3 and 4, $\ell$ =1, 2, 3 and 4, p=1, 2, 3, 4, 5, 6, 7 and 8) conditional probability vector calculation expression,

if $-1 < |\beta| \leq 1$, the output is determined as -1.

Also, if $2^3-1 < |\beta| \leq 2^3+1$, the output is determined as 1.

Also, if $2^4-1 < |\beta| \leq 2^4+1$, the output is determined as –1.

Also, if $3*2^3-1 < |\beta| \leq 3*2^3+1$, the output is determined as 1.

Also, if $2^5-1 < |\beta| \leq 2^5+1$, the output is determined as –1.

Also, if $2^2-1 < |\beta| \leq 2^2+1$, the output is determined as $0.9375\{|\beta|-2^2\}$.

Also, if $3*2^2-1 < |\beta| \leq 3*2^2+1$, the output is determined as $-0.9375\{|\beta|-3*2^2\}$.

Also, if $5*2^2-1 < |\beta| \leq 5*2^2+1$, the output is determined as $0.9375\{|\beta|-5*2^2\}$. Also, if $7*2^2-1 < |\beta| \leq 7*2^2+1$, the output is determined as $-0.9375\{|\beta|-7*2^2\}$. Also, if $1 < |\beta| \leq 2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}(|\beta|-1)-1$.

Also, if $2^2+1 < |\beta| \leq 2^3-1$, the output is determined as $\frac{0.0625}{2^2-2}(|\beta|-2^3+1)+1$.

Also, if $2^3+1 < |\beta| \leq 3*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}(2^3+1-|\beta|)+1$.

Also, if $6*2^2+1 < |\beta| \leq 7*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}(6*2^2+1-|\beta|)+1$.

Also, if $7*2^2+1 < |\beta| \leq 2^5-1$, the output is determined as $\frac{0.0625}{2^2-2}(2^5-1-|\beta|)-1$.

Next, for the fifth (that is, k=5, m=0, 1, 2, …7, 8, $\ell$ =1, 2, 3, …7, 8) conditional probability vector calculation expression,

if $-1 < |\beta| \leq 1$, the output is determined as –1.

Also, if $2^2-1 < |\beta| \leq 2^2+1$, the output is determined as 1.

Also, if $3*2^2-1 < |\beta| \leq 3*2^2+1$, the output is determined as –1.

Also, if $7*2^2-1 < |\beta| \leq 7*2^2+1$, the output is determined as 1.

Also, if $2^5-1 < |\beta| \leq 2^5+1$, the output is determined as –1.

Also, if $1 < |\beta| \leq 3$, the output is determined as $0.9375(|\beta|-2)$.

Also, if $5 < |\beta| \leq 7$, the output is determined as $-0.9375(|\beta|-6)$.

Also, if $9 < |\beta| \leq 11$, the output is determined as $0.9375(|\beta|-10)$.

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Also, if $25 < |\beta| \leq 27$, the output is determined as $0.9375(|\beta|-26)$.

Also, if $29 < |\beta| \leq 31$, the output is determined as $-0.9375(|\beta|-30)$.

Next, the calculation expressions of the sixth to tenth conditional probability vectors can be obtained by substituting $\beta$ with $\alpha$ in the first to fifth conditional probability vector according to the property of the first form.

**Fourth Embodiment**

The fourth embodiment of the present invention is a case corresponding to the second form and is applied the property of the second form. The fourth embodiment includes an example of 1024-QAM where the magnitude of QAM is 1024. The order selection of the received signal is intended to apply $\alpha$ at first.

A mathematical expression 1 determines the magnitude of QAM and a mathematical expression 2 shows the number of bits set in each point of a combination constellation diagram according to the magnitude of QAM, as is in the third embodiment.

【mathematical expression 1】

$2^{2n}$ – QAM, n = 2, 3, 4 ····

【mathematical expression 2】

the number of bits set in each point = 2n

Basically, the magnitude of QAM in the fourth embodiment of the present invention is determined as the above expression, and accordingly the number of the conditional probability vector value of the final output value becomes 2n.

A case where $2^{2*5}$ – QAM equals to 1024 – QAM according to the mathematical expression 1 and the number of bits set in each constellation point equals to 2 x 5 = 10 bits according to the mathematical expression 2 will be explained when n is 5 using such mathematical expressions 1 and 2. (referring to Figs. 13 and 14).

First, for the calculation of the first conditional probability vector,

if $|\alpha|>2^5-1$, the output is determined as -sign(α).

Also, if $|\alpha|\leq 1$, the output is determined as -0.9375sign(α).

Also, if $1<|\alpha|\leq 2^5-1$, the output is determined as $-sign(\alpha)[\frac{0.0625}{2^5-2}(|\alpha|-1)+0.9375]$.

Next, the second conditional probability vector calculation expression is a substitution form of the first calculation expression as follows.

ⓐ If $|\beta|>2^5-1$, the output is determined as –sign(β).

ⓑ if $|\beta|\leq 1$, the output is determined as –0.9375 sign(β).

ⓒ if $1<|\beta|\leq 2^5-1$, the output is determined as $-sign(\beta)\{0.0021(|\beta|-1)+0.9375$.

Next, for the third conditional probability vector calculation expression,

when $\alpha\beta\geq 0$,

ⓐ if $2^5-2^{5(2-m)}\leq|\alpha|<2^5-2^{5(2-m)}+1$, the output is determined as $(-1)^m$.

At this time, since m equals to 1 and 2, when substituting that,

if $0\leq|\alpha|<1$, the output is determined as –1.

Also, if $2^5-1\leq|\alpha|<2^5$, the output is determined as 1.

Also, ⓑ if $2^4-1\leq|\alpha|<2^4+1$, the output is determined as $0.9375(|\alpha|-2^4)$.

Also, ⓒ if $2^4-2^{4(2-m)}+m\leq|\alpha|<2^5-2^{4(2-m)}+m-2$, the output is determined as

$$\frac{0.0625}{2^4-2}(|\alpha|-2m+1)+0.9735(-1)^m-0.0625$$

Here, when substituting m=1, 2,

if $1 \leq |\alpha| < 2^4-1$, the output is determined as $\frac{0.0625}{2^4-2}(|\alpha|-1)-1$.

Also, if $2^4+1 \leq |\alpha| < 2^5-1$, the output is determined as $\frac{0.0625}{2^4-2}(|\alpha|-3)+0.825$.

When $\alpha\beta < 0$,

in this case, the calculation expression is obtained by substituting $\alpha$ with $\beta$ in the expressions ⓐ,ⓑ,ⓒ of the method for determining the output of the third conditional probability vector described just above.

Next, for the fourth (that is, k=4, m=0, 1, 2, $\ell$ =1, 2, p=1, 2, 3, 4) conditional probability vector calculation,

When $\alpha\beta \geq 0$,

ⓐ if $m*2^4-1 \leq |\alpha| < m*2^4+1$, the output is determined as $(-1)^{m+1}$.

At this time, substituting m=0, 1, 2, if $-1 < |\alpha| \leq 1$, the output is determined as -1.

Also, if $2^4-1 \leq |\alpha| < 2^4+1$, the output is determined as 1.

Also, if $2^5-1 \leq |\alpha| < 2^5+1$, the output is determined as –1.

Also, ⓑ if $(2\ell-1)*2^3-1 \leq |\alpha| < (2\ell-1)*2^3+1$, the output is determined by substituting $\ell$ =1, 2 in the $(-1)^{\ell+1}\{0.9375|\alpha|-0.9375(2\ell-1)*2^3\}$,

here, if $2^3-1 \leq |\alpha| < 2^3+1$, the output is determined as $0.9375(|\alpha|-2^3)$.

Also, if $3*2^3-1 \leq |\alpha| \leq (3*2^3+1$, the output is determined as $-0.9375(|\alpha|-3*2^3)$.

Also, ⓒ if $(P-1)*2^3+1 \leq |\alpha| \leq P*2^3-1$ and P is an odd number, the output is determined as $\frac{0.0625}{2^3-2}[(-1)^{(p+1)/2+1}*|\alpha|+(-1)^{(p+1)/2}(P-1)*2^3+1]+(-1)^{(p+1)/2}$.

However, if P is an even number, the output is determined as

$$\frac{0.0625}{2^3-2}[(-1)^{p/2+1}*|\alpha|+(-1)^{p/2}(P*2^3-1)]+(-1)^{p/2+1}$$.

Here, when substituting p=1, 2, 3, 4,

if $1<|\alpha| \leq 2^3-1$, the output is determined as $\frac{0.0625}{2^3-2}[|\alpha|-1]-1$.

Also, if $2^3+1<|\alpha| \leq 2^4-1$, the output is determined as $\frac{0.0625}{2^3-2}[|\alpha|-2^4+1]+1$.

Also, if $2^4+1<|\alpha| \leq 3*2^3-1$, the output is determined as $\frac{0.0625}{2^3-2}[2^4+1-|\alpha|]+1$.

Also, if $3*2^3+1<|\alpha| \leq 2^5-1$, the output is determined as $\frac{0.0625}{2^3-2}[2^5+1-|\alpha|]-1$.

When $\alpha\beta<0$,

in this case, the calculation expression is obtained by substituting $\alpha$ with $\beta$ in the expressions of ⓐ, ⓑ, ⓒ of the method for determining the output of the fourth conditional probability vector described just above.

Next, for the fifth (that is, k=5, m=0, 1, 2, 3, 4, $\ell$ =1, 2, 3, 4) conditional probability vector,

(1) when $\alpha\beta \geq 0$,

ⓐ if $m*2^3-1<|\alpha| \leq m*2^3+1$, the output is determined as $(-1)^{m+1}$.

At this time, when substituting m=0, 1, 2, 3, 4,

if $-1<|\alpha| \leq 1$, the output is determined as -1.

Also, if $2^3-1<|\alpha| \leq 2^3+1$, the output is determined as 1.

Also, if $2^4-1<|\alpha| \leq 2^4+1$, the output is determined as –1.

Also, if $3*2^3-1<|\alpha| \leq 3*2^3+1$, the output is determined as 1.

Also, if $2^5-1<|\alpha| \leq 2^5+1$, the output is determined as -1.

Also, ⓑ if $(2\ell-1)*2^2-1<|\alpha| \leq (2\ell-1)*2^2+1$, the output is determined by substituting $\ell$ =1, 2, 3, 4 in the

$(-1)^{\ell+1}0.9375\{|\alpha|-0.9375(2\ell-1)*2^2\}$,

here, if $2^2-1<|\alpha| \leq 2^2+1$, the output is determined as $0.9375(|\alpha|-2^2)$.

Also, if $3*2^3-1<|\alpha| \leq 3*2^3+1$, the output is determined as $-0.9375(|\alpha|-3*2^2)$.

Also, if $5*2^2-1<|\alpha| \leq 5*2^2+1$, the output is determined as $0.9375(|\alpha|-5*2^2)$.

Also, if $7*2^2-1<|\alpha| \leq 7*2^2+1$, the output is determined as $-0.9375(|\alpha|-7*2^2)$.

Also, ⓒ when $(P-1)*2^2+1<|\alpha| \leq P*2^2-1$, and substituting p=1, 2, 3, …7, 8 according to whether P is an odd number or an even number,

if $1<|\alpha| \leq 2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}[|\alpha|-1]-1$.

Also, if $2^2+1<|\alpha| \leq 2^3-1$, the output is determined as $\frac{0.0625}{2^2-2}[|\alpha|-2^3+1]+1$.

Also, if $2^3+1<|\alpha| \leq 3*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}[2^3+1-|\alpha|]+1$.

Also, if $3*2^2+1<|\alpha| \leq 2^4-1$, the output is determined as $\frac{0.0625}{2^2-2}[2^4-1-|\alpha|]-1$.

Also, if $2^4+1<|\alpha| \leq 5*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}[|\alpha|-2^4-1]-1$.

Also, if $5*2^2+1<|\alpha| \leq 6*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}[|\alpha|-6*2^2+1]+1$.

Also, if $6*2^2+1<|\alpha| \leq 7*2^2-1$, the output is determined as $\frac{0.0625}{2^2-2}[6*2^2+1-|\alpha|]+1$.

Also, if $7*2^2+1<|\alpha| \leq 2^5-1$, the output is determined as $\frac{0.0625}{2^2-2}[2^5-1-|\alpha|]-1$.

When $\alpha\beta<0$,

in this case, the calculation expression is obtained by substituting $\alpha$ with $\beta$ in the ⓐ,ⓑ,ⓒ expressions of the method for determining the fifth conditional probability vector ($\alpha\beta<0$) described just above.

Next, for the sixth conditional probability vector (that is, k=6, m=0, 1, 2, … 7, 8,

$\ell$ =1,2,3,...7,8),

(1) when $\alpha\beta \geq 0$,

ⓐ if $m*2^2-1<|\alpha| \leq m*2^2+1$, the output is determined as $(-1)^{m+1}$.

At this time, the output is obtained by applying m=0, 1, 2, ...7, 8.

That is, if $-1<|\alpha| \leq 1$, the output is determined as -1.

Also, if $2^2-1<|\alpha| \leq 2^2+1$, the output is determined as 1.

Also, if $3*2^2-1<|\alpha| \leq 3*2^2+1$, the output is determined as -1.

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Also, if $7*2^2-1<|\alpha| \leq 7*2^2+1$, the output is determined as 1.

Also, if $2^5-1<|\alpha| \leq 2^5+1$, the output is determined as -1.

Also, ⓑ if $(2\ell -1)*2-1<|\alpha| \leq (2\ell -1)*2+1$,

the output is determined by substituting $\ell$ =1, 2, 3,...7,8 in the

$(-1)^{\ell+1}\{0.9375|\alpha|-0.9375(2\ell -1)*2\}$,

here, if $1<|\alpha| \leq 3$, the output is determined as $0.9375(|\alpha|-2)$.

Also, if $5<|\alpha| \leq 7$, the output is determined as $-0.9375(|\alpha|-6)$.

Also, if $9<|\alpha| \leq 11$, the output is determined as $0.9375(|\alpha|-10)$.

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Also, if $25<|\alpha| \leq 27$, the output is determined as $0.9375(|\alpha|-26)$.

Also, if $29<|\alpha| \leq 31$, the output is determined as $-0.9375(|\alpha|-30)$.

(2) When $\alpha\beta<0$,

in this case, the calculation expression is obtained by substituting $\alpha$ with $\beta$ in the ⓐ, ⓑ expressions of the method for determining the output of the fifth conditional probability vector ($\alpha\beta \geq 0$) described just above.

Next, the calculation expressions of the seventh to tenth conditional probability vector

are obtained by substituting α with β and β with α in the calculation expressions of the third to sixth conditional probability vector.

Fig. [[11]] 14 is a view showing a functional block for a conditional probability vector decision process in accordance with the present invention.

Fig. [[12]] 15 is a view showing an example of hard ware configuration for a conditional probability vector of a first form of 64-QAM in accordance with the present invention. A person skilled in the art can configure the hard ware by making a modification within the scope of the present invention.

While the present invention has been described in conjunction with preferred embodiments thereof, it is not limited by the foregoing description, but embraces alterations, modifications and variations in accordance with the spirit and scope of the appended claims.

**Industrial Applicability**

In accordance with the present invention, it is expected to enhance the process speed remarkably and to save a manufacturing cost upon embodying hard ware by applying a linear conditional probability vector equation instead of a log likelihood ratio method being soft decision demodulation method of a square QAM signal that is generally used in the industrial field.

## ABSTRACT

~~The present invention relates to a demodulation method using soft decision for QAM (Quadrature Amplitude Modulation).~~ In a soft decision method for demodulation of a received ~~signal of~~ square QAM (Quadrature Amplitude Modulation) signal, ~~comprised of the same phase signal component and a orthogonal phase signal component, the demodulation method using soft decision has a characteristic wherein~~ the processing speed is improved, and the manufacturing expense is reduced, by ~~gaining a~~ using condition probability vector ~~value~~ values, which ~~is each~~ are soft decision ~~value~~ values. ~~corresponding to a beat position of hard decision using a function which includes a~~ A condition ~~judgement~~ judgment operation is employed. ~~from a orthogonal phase component value of a received signal and the same phase component value.~~